NASA CR-177882

(NASA-CR-177882) [THE HXII GAS SYSTEM] Final Report (California Inst. of Tech.) 24 p HC A02/MF A01 CSCL 14B
N86-28386
Unclas
G3/35 43416

HXII Final Report

California Institute of Technology

Introduction

The following report includes work done over the past year and a half to develop two gas proportional counters of substantially different designs. Since both detectors were to operate at high energy (5-60 keV), it was necessary to employ xenon gas to provide significant absorption for the harder photons, and to use the xenon gas at pressures of two to three atmospheres. The excessive cost of xenon demands that a suitable recovery and purification system be constructed to make the large quantities of xenon required in the experiment reusable after it becomes contaminated.

The two detector designs included a detector patterned after our HEAO-1 design which possesses a proven low background capability at atmospheric pressure, and a parallel planar geometry detector with an extensive drift region. The deep drift region is necessary since the planer detector requires substantial high voltage levels to operate at plane separations of a few millimeters, a depth of gas that is inadequate to absorb X-rays above even ten keV. The cost of fabricating large numbers of planes to fill an adequate absorbing depth is prohibitive.

The purpose of the proposed investigation was to design and fabricate test counters based on the above requirements and to evaluate their actual performance with emphasis on background rejection efficiency and position resolution.

Multicell Proportional Counter (HEAO-1 Design)

In order to save costs on the fabrication of the grid planes for the multicell detector, the prototype detector for the GSFC OSO-8 experiment

was used, courtesy of E. Boldt and P. Serlemitsos of Goddard Space Flight Center. The anode wires in the layer immediately behind the detector window were replaced with 0.8 mil stainless steel wires to increase their resistance and thereby slow down the pulse risetime to make it easier to measure. The position is determined by comparing the risetime of the signals at each end of the wire.

The mechanical design of the detector followed the design of previously flown counters, except that the pressure to be used was three times higher. For the laboratory version a stress analysis was performed on aluminum alloys to size the thickness of the detector housing and the support collimator for the window of the detector. Since weight was not a constraint for the lab unit, and costs were to be minimized, solid walls were employed. The window support collimator was of a standard design used on HEAO and quite expensive to fabricate, so a simple slotted aluminum plate was used to provide small windows for testing with radioactive sources.

The elements of the mechanical design consisted of computing the maximum stress and deflection of the walls of the detector using the relationships $S_{max} = \frac{1}{8} \frac{WLC}{I}^{*}$ and $y_{max} = -\frac{5}{32} \frac{WL^3}{Ebh^3}^{*}$ for stress and deflection respectively. The material was 2024 T6 aluminum, since no welds were required. A drawing of the detector is enclosed as well as a photograph.

The first test was to determine whether the detector background was a strong function of pressure. Figure 3 shows the properties of the detector at one atmosphere pressure of 90% xenon and 10% methane. A Co^{60} source was used to simulate the cosmic ray background conditions observed in orbit. At 3 atmospheres, the background was not supressed as well as at one atmosphere. This result was expected since a larger fractic

*See Appendix A.

the Compton recoil electron tracks will terminate within one cell of the detector at the higher pressure and fail to be anticoincidenced out by passing between cells. This is probably the major source of background.

The position resolution of the detector is definitely adequate to resolve one centimeter as can be seen from Figure 3 . At 3 atmospheres the resolution is not quite as good. This is expected since the ionization charge cloud has more time to diffuse, since the collection times are longer.

Planar Drift Counter

The drift counter design is based on a planar geometry using parallel planes of wire grids. This counter geometry has been used extensively and is the design used for the HEAO-B IPC system (Humphrey et al. 1977, IEEE, Nucl. Sci. Symp.). Since the purity of the xenon is known to be important to prevent recombination of the electrons produced in the absorbing region, it was decided to use macor, a machinable glass ceramic material to construct the frames for the wiregrids. In order that the wiregrids could be modified, a method had to be devised to disassemble the grids. Since the macor frames are machinable, holes were drilled in the macor and nickel plated pins were inserted into the holes. The grid wires are attached to the pins by a crimp pin. The stainless steel wire can be spot-welded to the nickel plated pins as well.

The mechanical design of the gas box, made from aluminum,was based on a 2 atmosphere filling with xenon. One quarter of the gas box was fitted with a collimator. The grid planes were envisioned to occupy a quadrant of the box as well, so that a reasonable number of wires could

be strung without exceeding the stress limit of the macor-supported frame. The design stress analysis is given in Appendix A.

The detector was first fitted with 3 mil stainless steel grid planes for both the anode and cathode planes. After a number of attempts, this configuration was not usable, since the high voltage required to make it operate exceeded the 6 kV limit of our supply. The anode plane was restrung using one mil tungsten wire. This modification was successful and good operation was obtained at an anode-cathode potential difference of 3.2 kV. The set of cathodes and anodes were then lowered to the middle of the gas box, making equal drift regions above and below the grid planes. Two hundred volts between the cathodes and the walls of the counter was adequate to obtain good electron collection as determined by the energy resolution of the counter at 6 keV.

The cathode and anode planes were then wired up in such a way as to create a total of nine cells in a square matrix with the middle cell being about 2 inches on a side. This is about the scale of a subcollimator cell. This configuration was then tested for background rejection using Co^{60} gamma-rays. The results are shown in Figure 6 where the upper curve has no anticoincidence, and the lower curve has the eight cells adjacent to the central cell in anticoincidence with the events occurring in the central cell. This degree of rejection is typical for P-10 gas at one atmosphere employing anticoincidence cells of the size used here. Smaller cell dimensions would probably improve the rejection efficiency, since a larger fraction of the Compton recoil electrons would pass through from one cell to the next.

Figure 1 - The background rejection of Compton recoil electrons produced by gamma rays from Co^{60} in one atmosphere of xenon. The detector is of the OSO-8/HEAO-1 design.

Figure 2 - The background rejection of Compton recoil electrons with 3 atmospheres of xenon. The normalization between Figure 1 and 2 is arbitrary.

Figure 3 - The position resolution of the stainless steel 0.0008 inch wire in 1.1 atmospheres of xenon. The wire length was 40 cm.

Figure 4 - The OSO-8 prototype detector mounted on the top plate of the counter gas box.

Figure 5 - The drift counter box showing the window support over one quadrant.

Figure 6 - The rejection of Co^{60} gamma-ray background in the planar counter using P-10 gas at 1.1 atmosphere pressure, and the full drift region. The upper curve is with no anticoincidence and the lower curve is with the anticoincidence turned on.

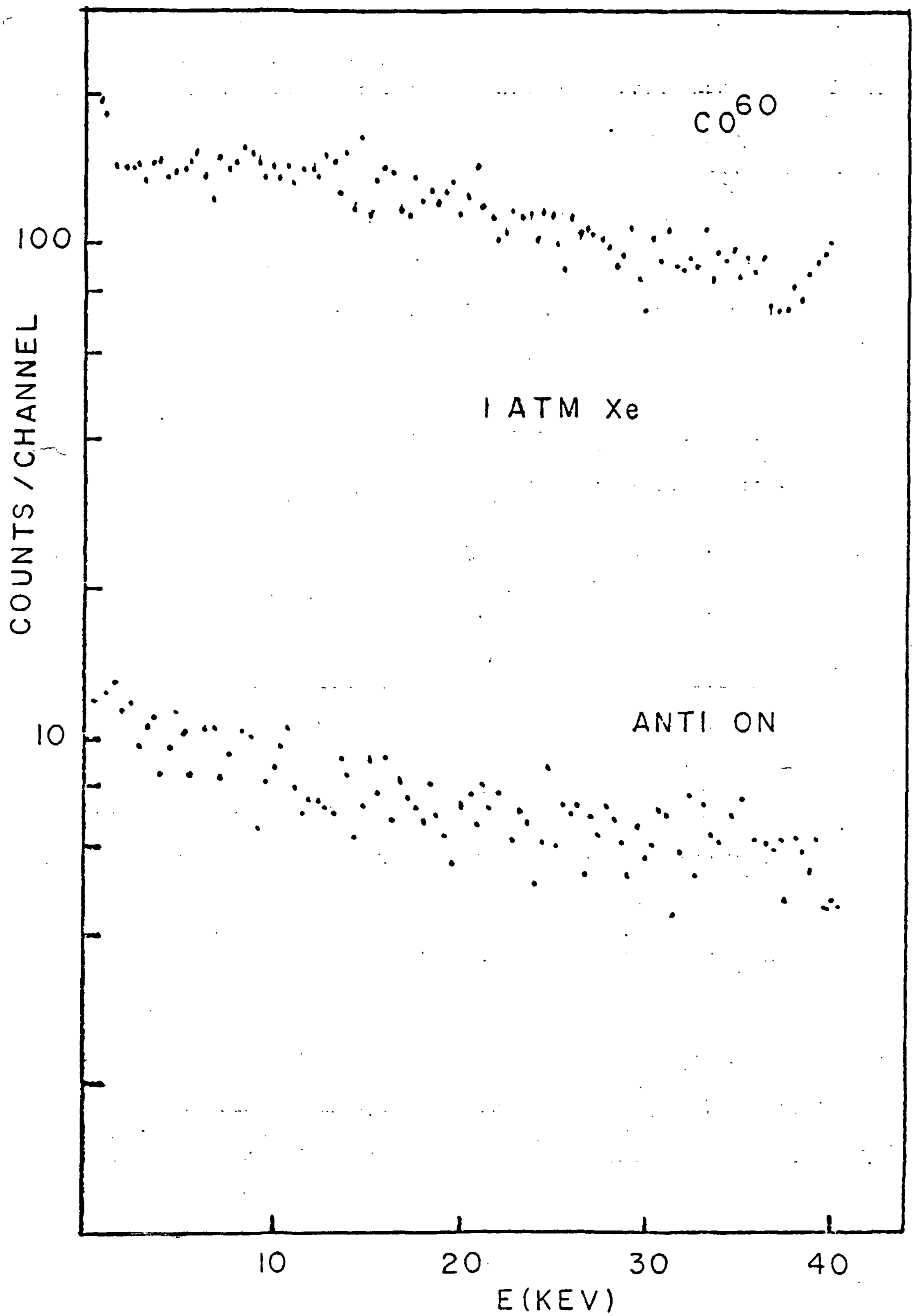


Fig. 1

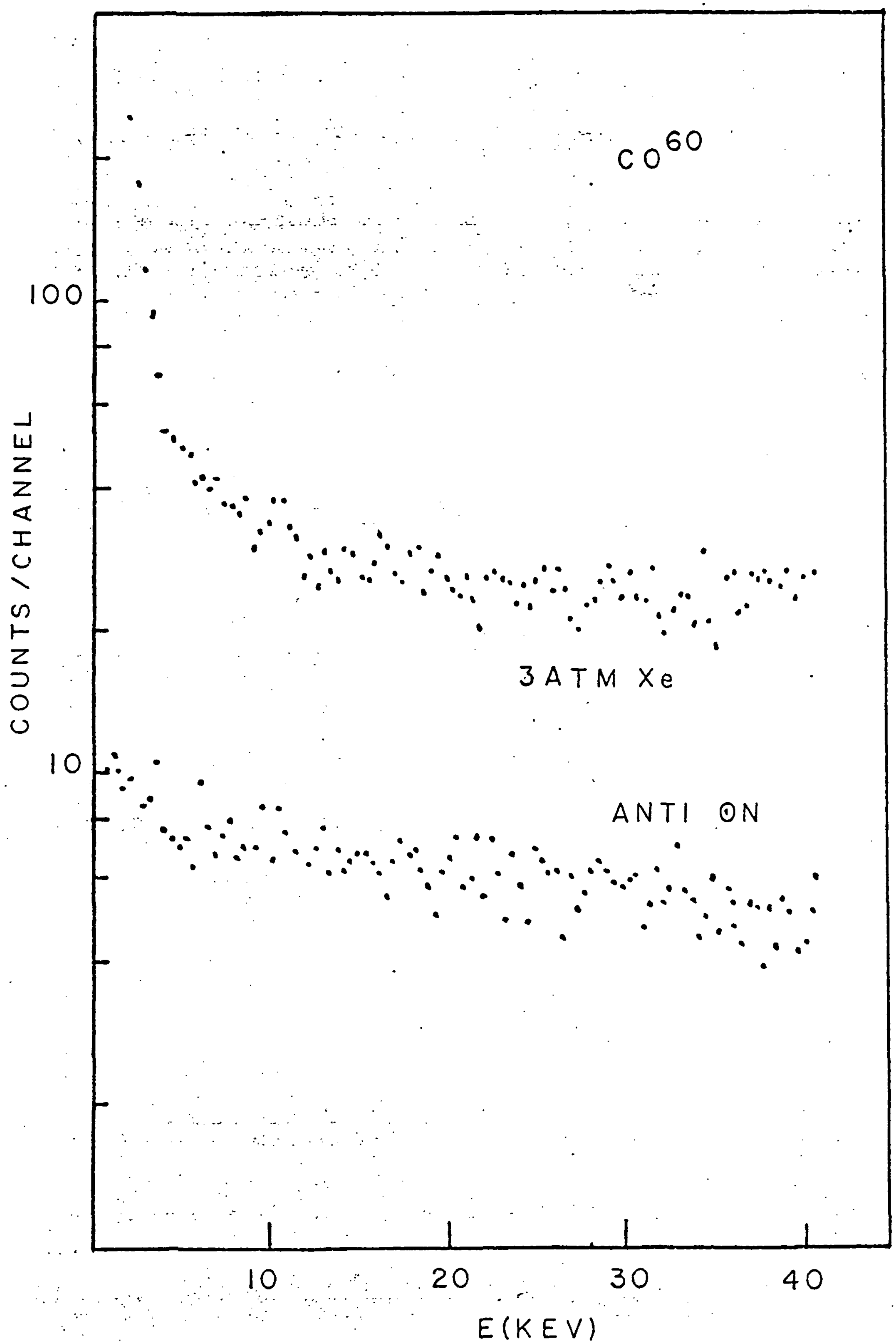


Fig. 2

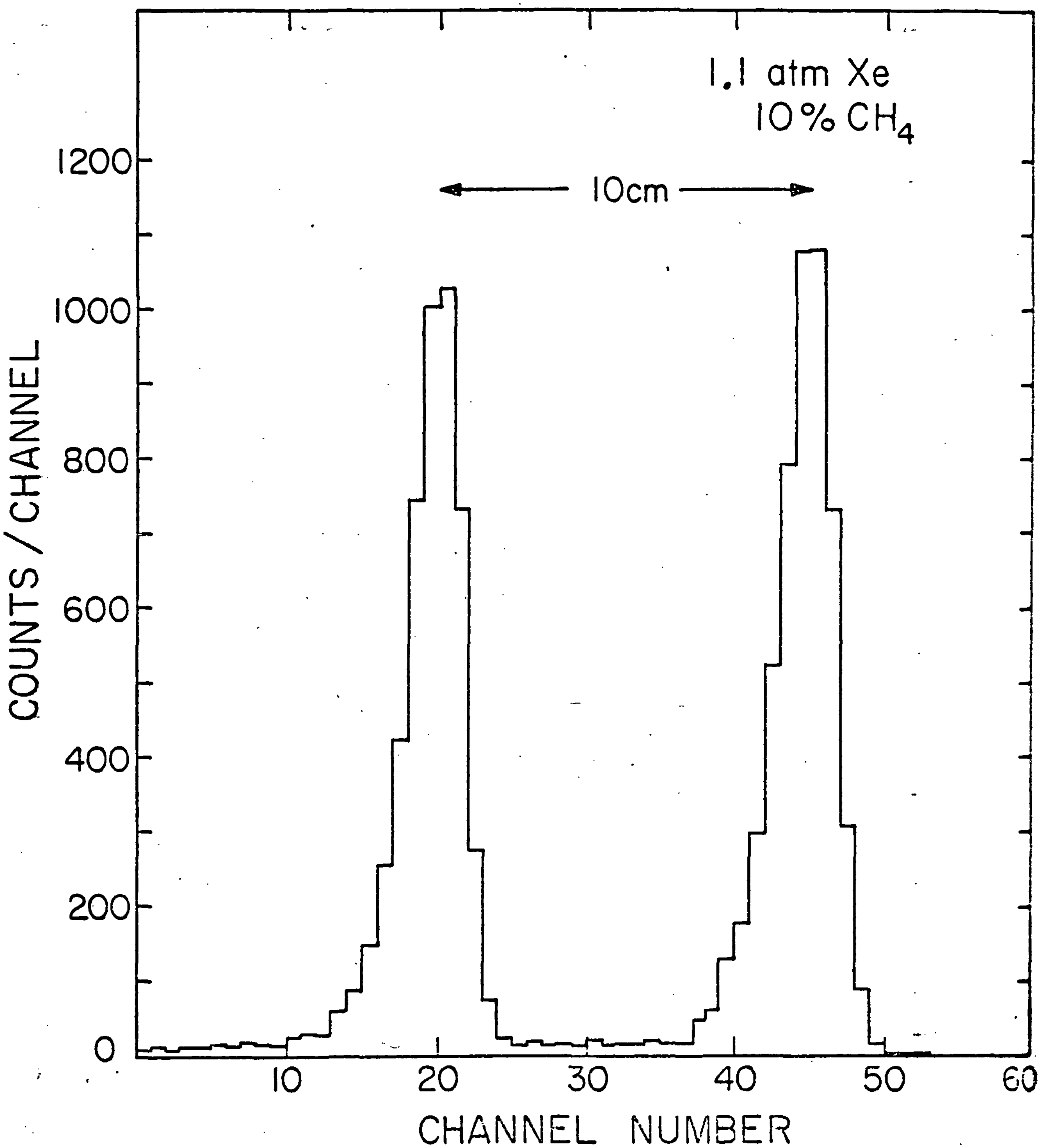
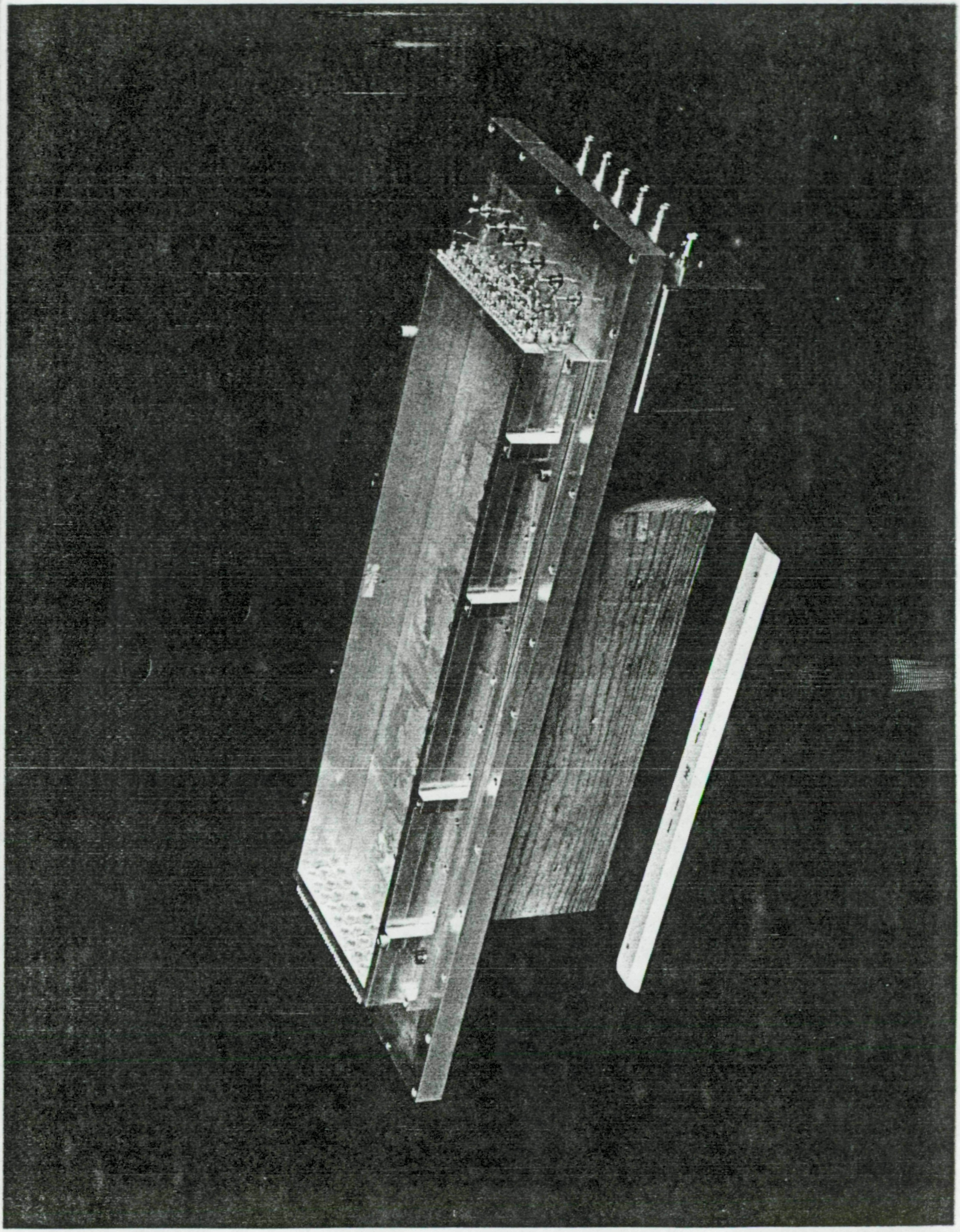

1.1 atm Xe
10% CH_4
10cm
COUNTS / CHANNEL
1200
1000
800
600
400
200
0
10
20
30
40
50
60
CHANNEL NUMBER

Fig. 3

ORIGINAL PAGE IS
OF POOR QUALITY



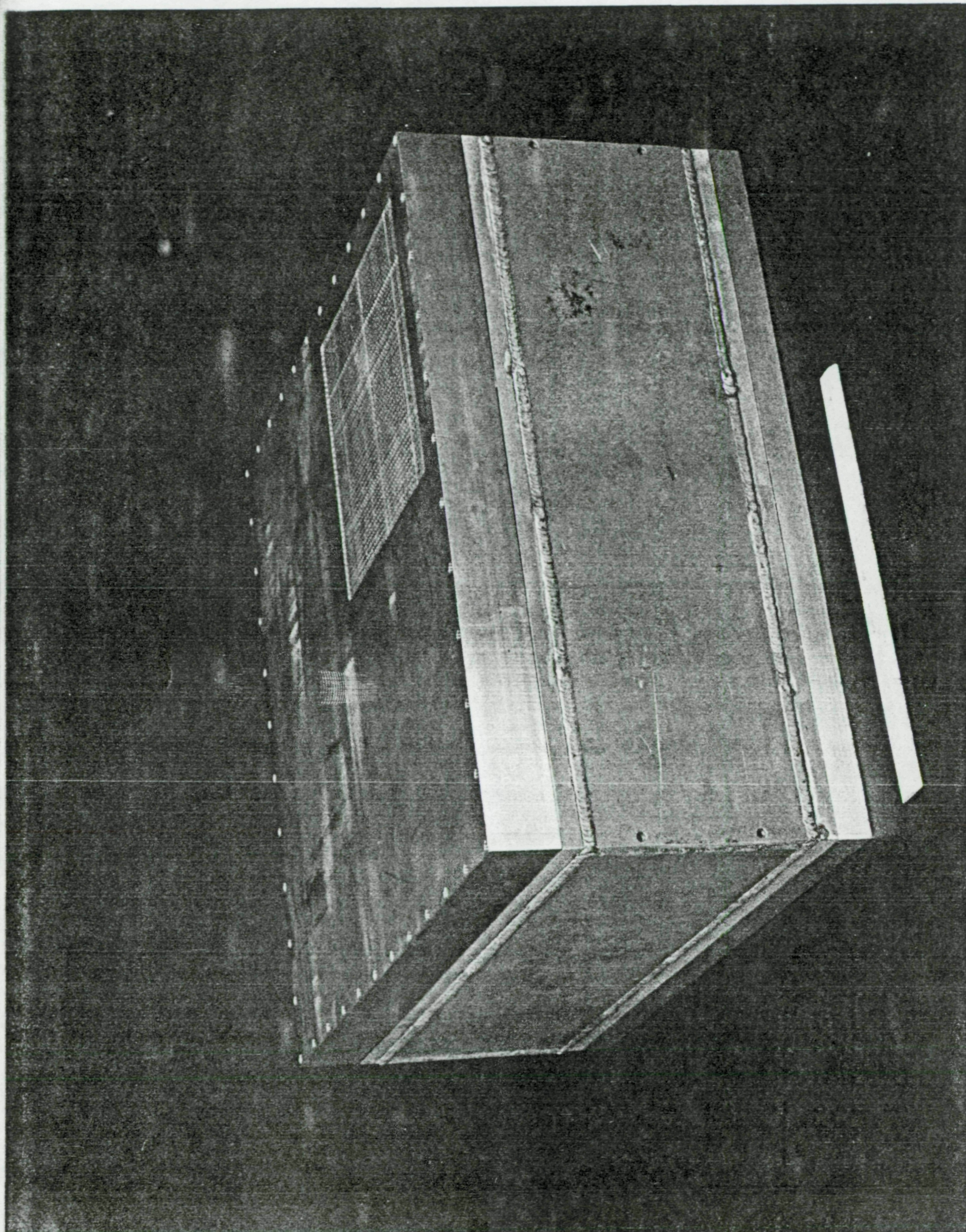
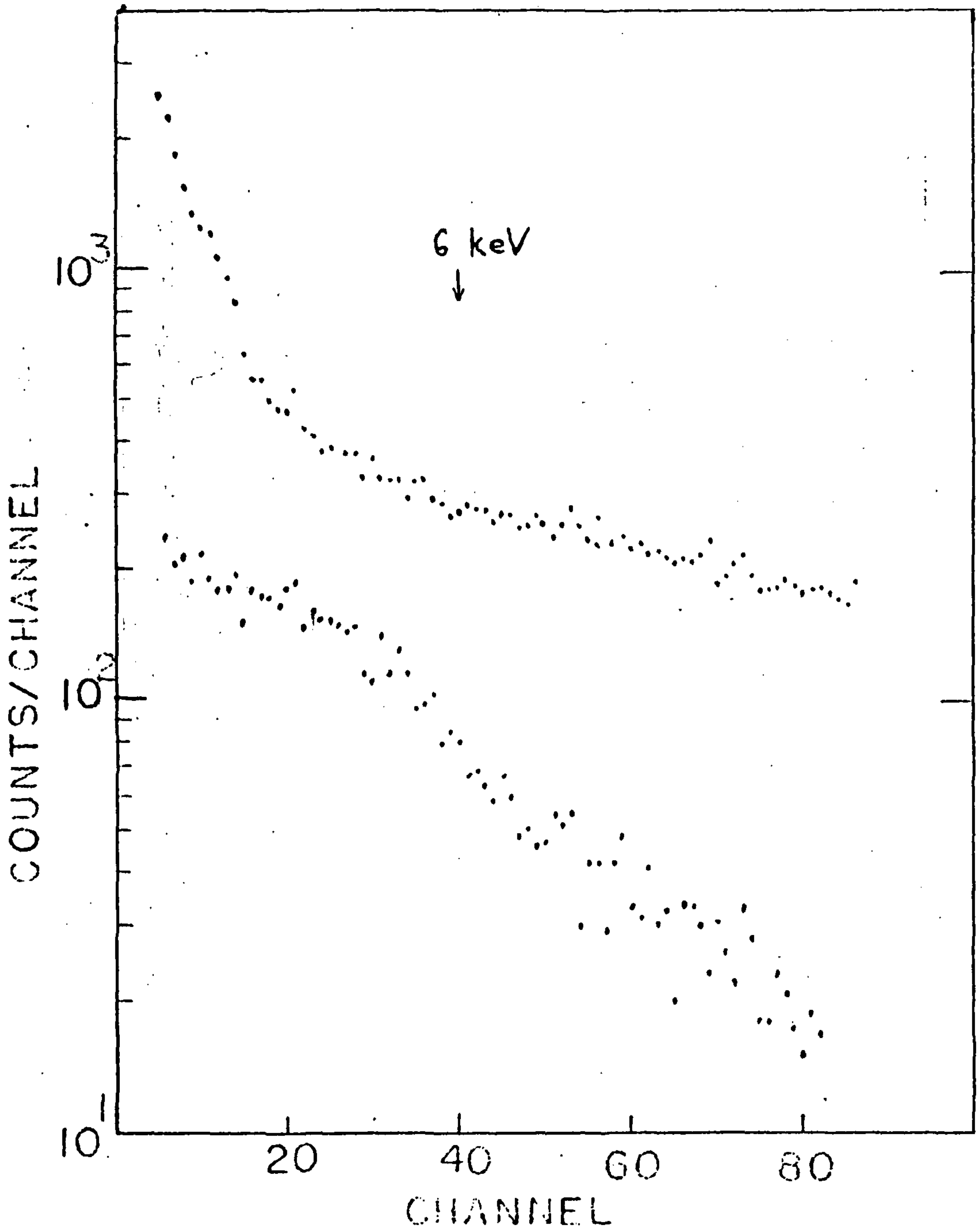


Fig. 5



COUNTS/CHANNEL
10^3
10^2
10^1
6 keV
20
40
60
80
CHANNEL

APPENDIX A

Design Parameters of Detectors, and Drawings

Large Square Detector 8" x 22.4" x 22.4"

Sideplate deflection

$S_{max} = \frac{WLc}{8I} \quad I = 1/12\ bh^3 \quad c = 1/2$

$= 1411$ psi   2 atmospheres with one inch wall

$= 5645$ 1/2 inch wall okay

$y_{max} = \frac{5}{384}\ \frac{WL^3}{EI}$

$= 1.9$ thousandths   1 inch wall

$= 15$ thousandths   1/2 inch wall

Cover - no clamping - worst case

$S_{max} = WLc/8I$

$= 450$ psi   1 inch thick plate

$y_{max} = 0.2$ thousandths

Collimator

Basic element of collimator is a strip of aluminum 9.5" long (quadrant collimator), 2" deep (1" slots), 0.020" thick.

Load = W = 107 lbs

$S_{max} = 1/8\ WLc/I \quad I = 1/12\ bh^3$

$= 38.119$ psi   7075 Al needed

$y_{max} = -5/384\ WL^3/EI$

$= 0.011"$

OSO-8 Prototype Gas Box

The old box was not adequate for 3 atmospheres of pressure.

Front and back plates 23.6" x 7.6" x 3/4"

$S_{max} = \frac{3}{4}\, WL/bh^2$ 3 atmospheres

$= 4528$ psi using the 7.6" span = L

This is safe for 2024 Al, even with a few slots for X-ray inputs.

Sides 23.6" x 2" x 3/4". This is very safe from above equation.

The thickness is large only so "O" ring grooves and screw holes can be fitted into the edges.

Macor Frames

The grid planes are made from macor bars of dimension 0.45" x 9.3" x 0.25". The wires in the grid plane are under a tension of 35 grams and are spaced 0.10" apart. The mechanical properties of the macor are:

modulus of rupture = 15,000 psi

modulus of elasticity = 9.3×10^6 psi

thermal expansion = 94×10^{-7}/°C.

To compute the total stress, take the tension of 35 gms per wire which gives a total of 6.9 lbs. along the 9-inch length of the bar.

$S_{max} = 3/4\ WL/bh^2$

gives

$S_{max} = 950$ psi which allows plenty of margin.

$y_{max} = -\frac{5}{384}\ WL^3/EI$

$= 0.004"$

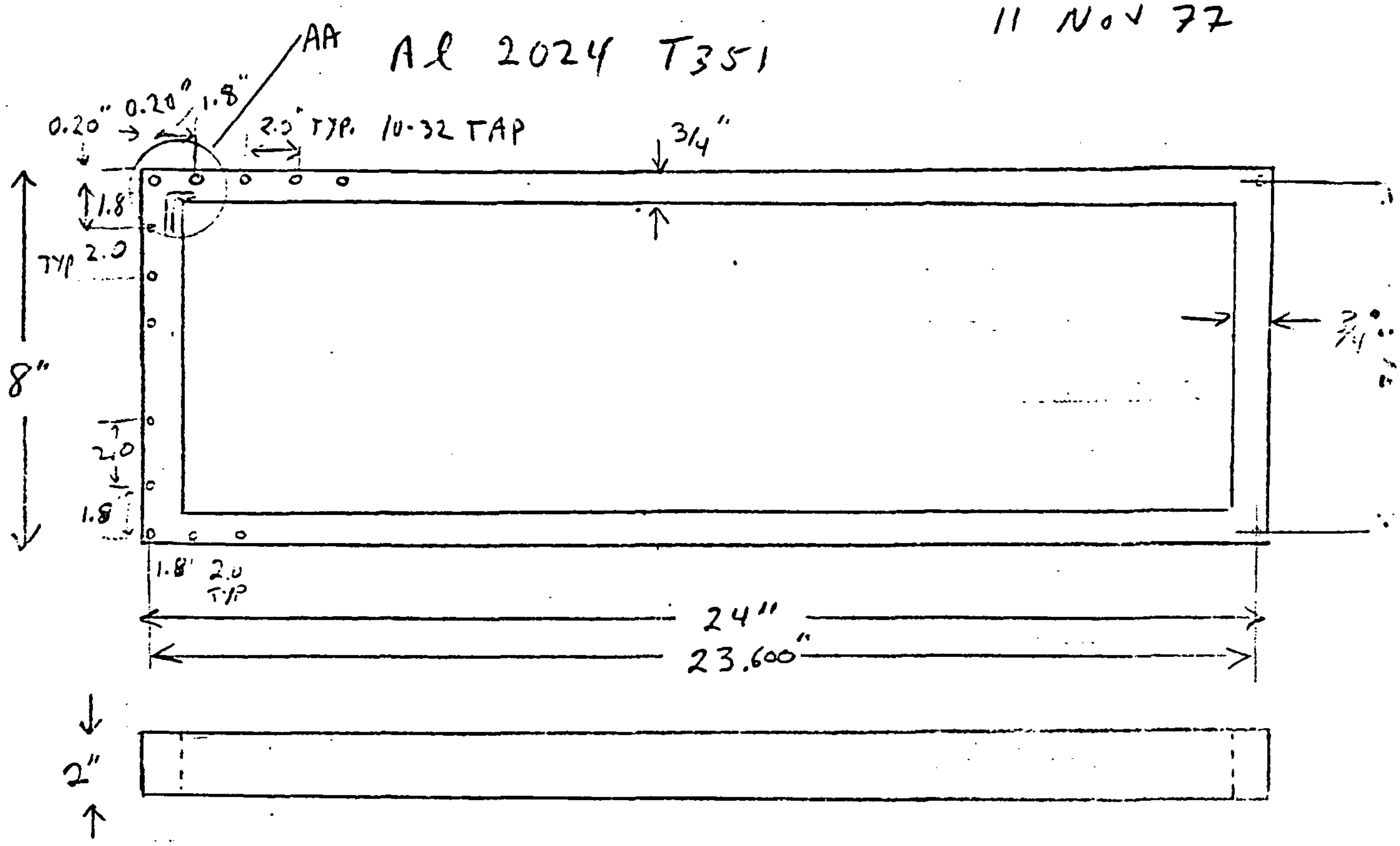
For this amount of flexing, prestressing of the bar is required to prevent sag as the wires are attached.

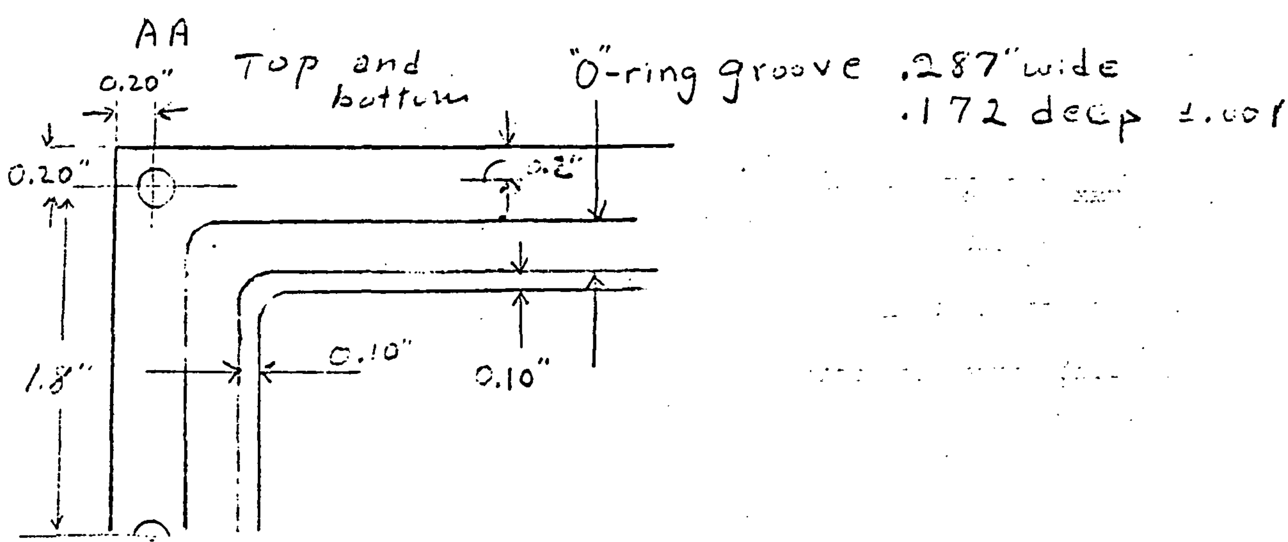
22 x 6½ x 1½

Ph99 6005-6
W.O. —
HX11 Gas Box
G. Garmire
11 Nov 77

Body

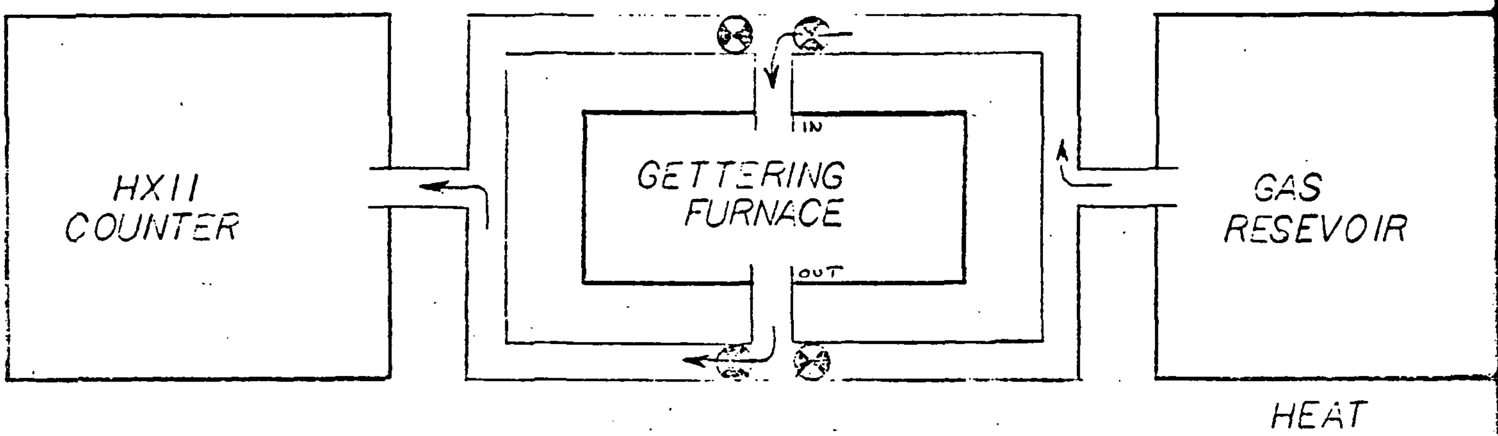
Al 2024 T351



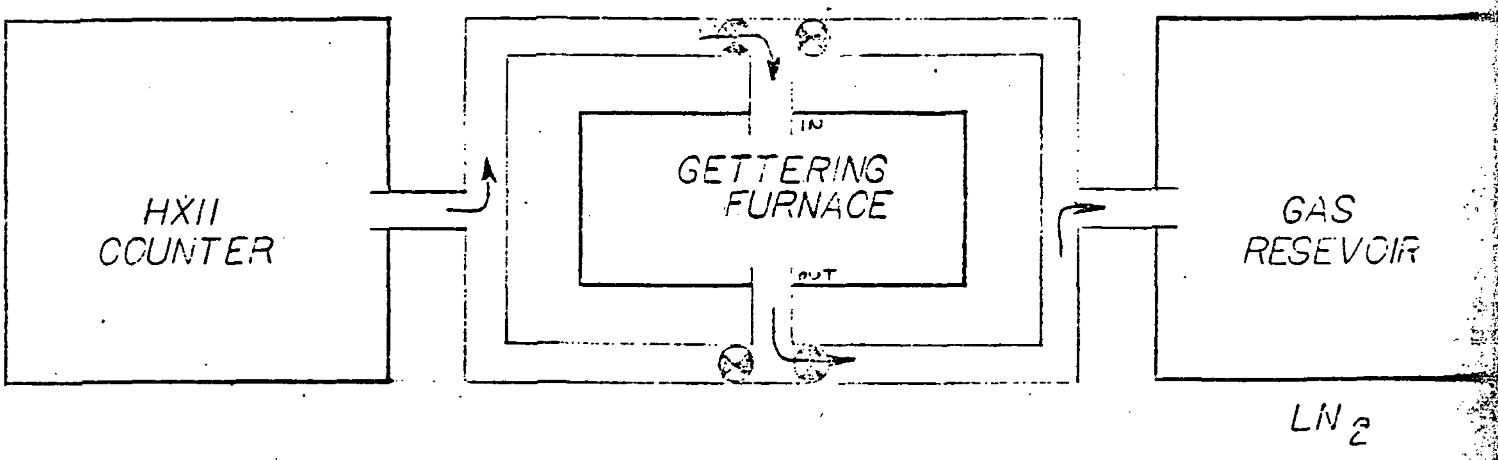


HXII GAS PURIFICATION SYSTEM

HOT CYCLE



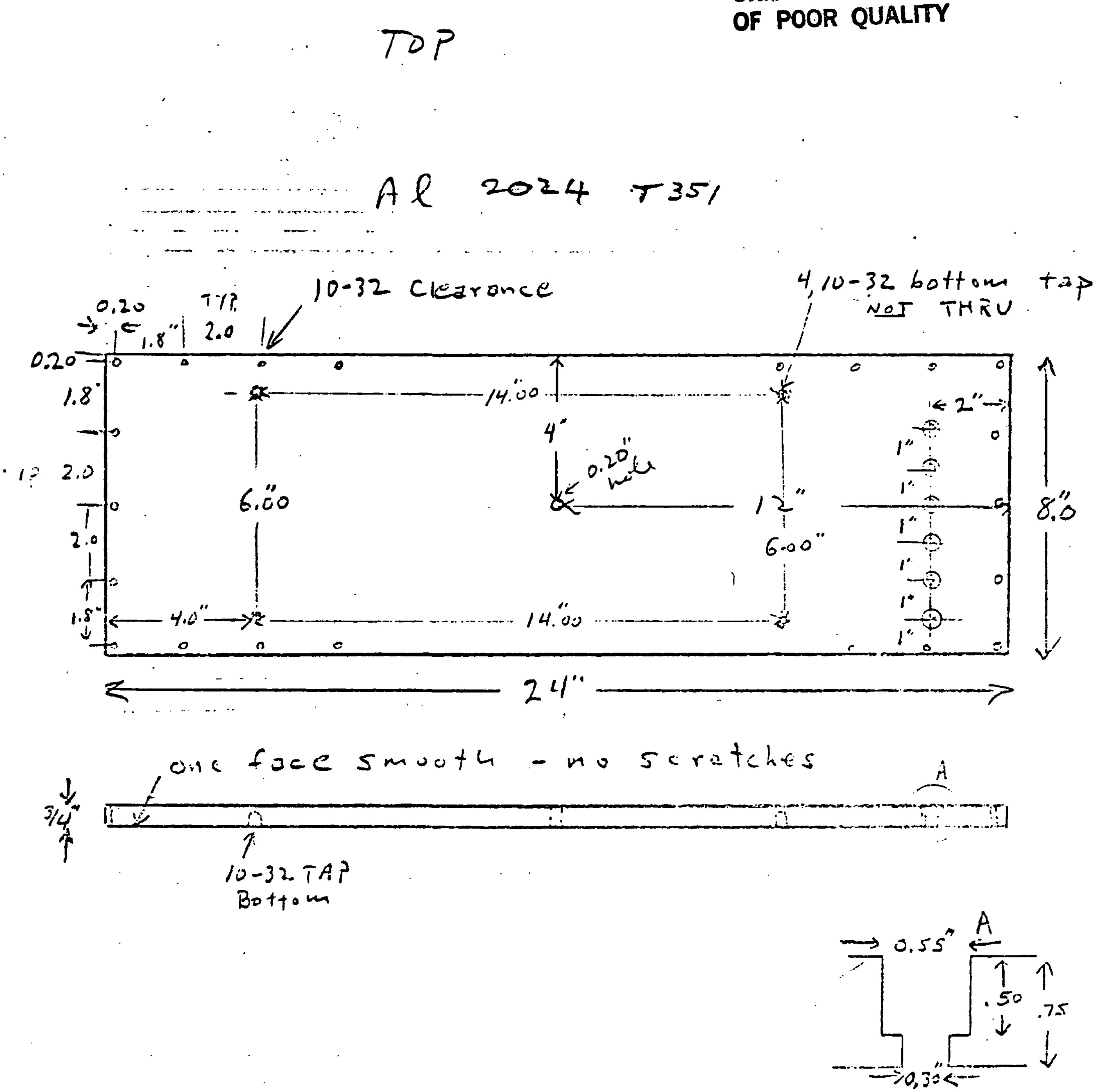
COLD CYCLE



- OPEN VALVE

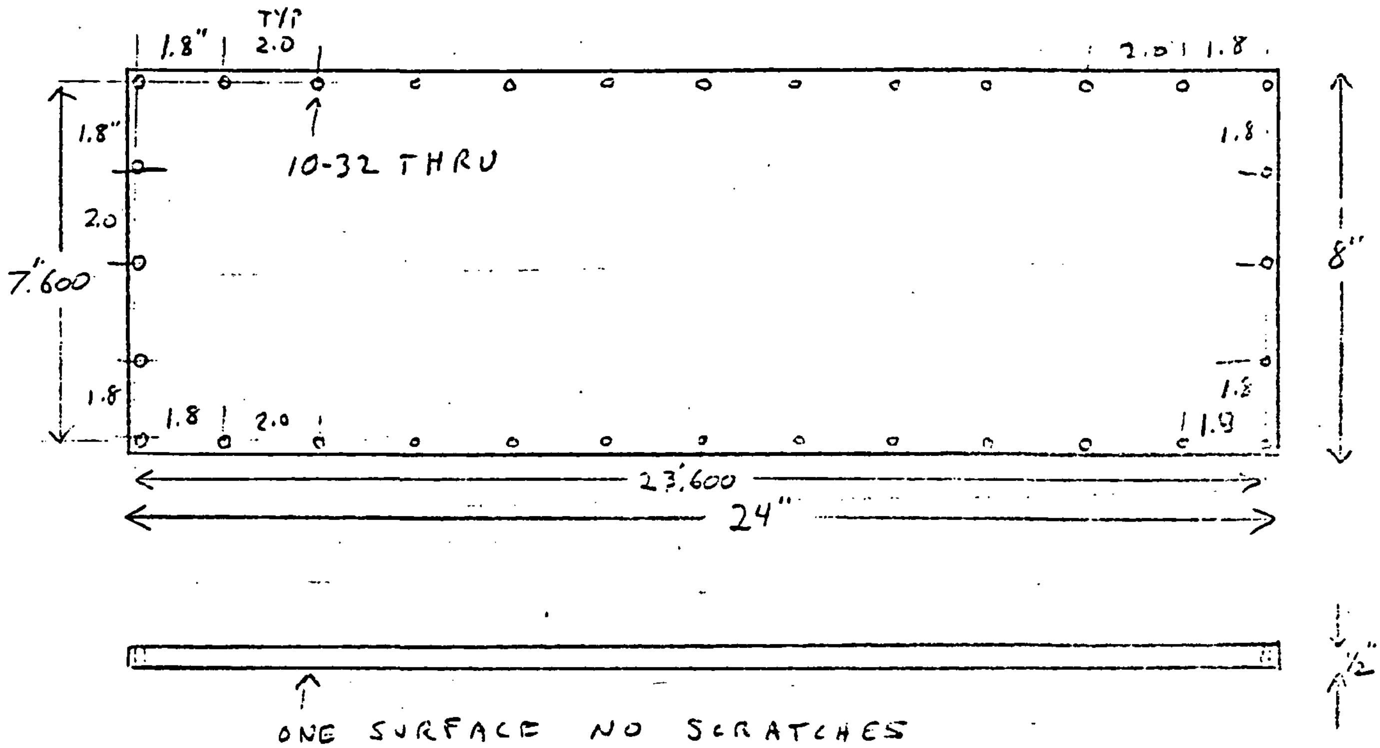
- CLOSED VALVE

ORIGINAL PAGE IS
OF POOR QUALITY



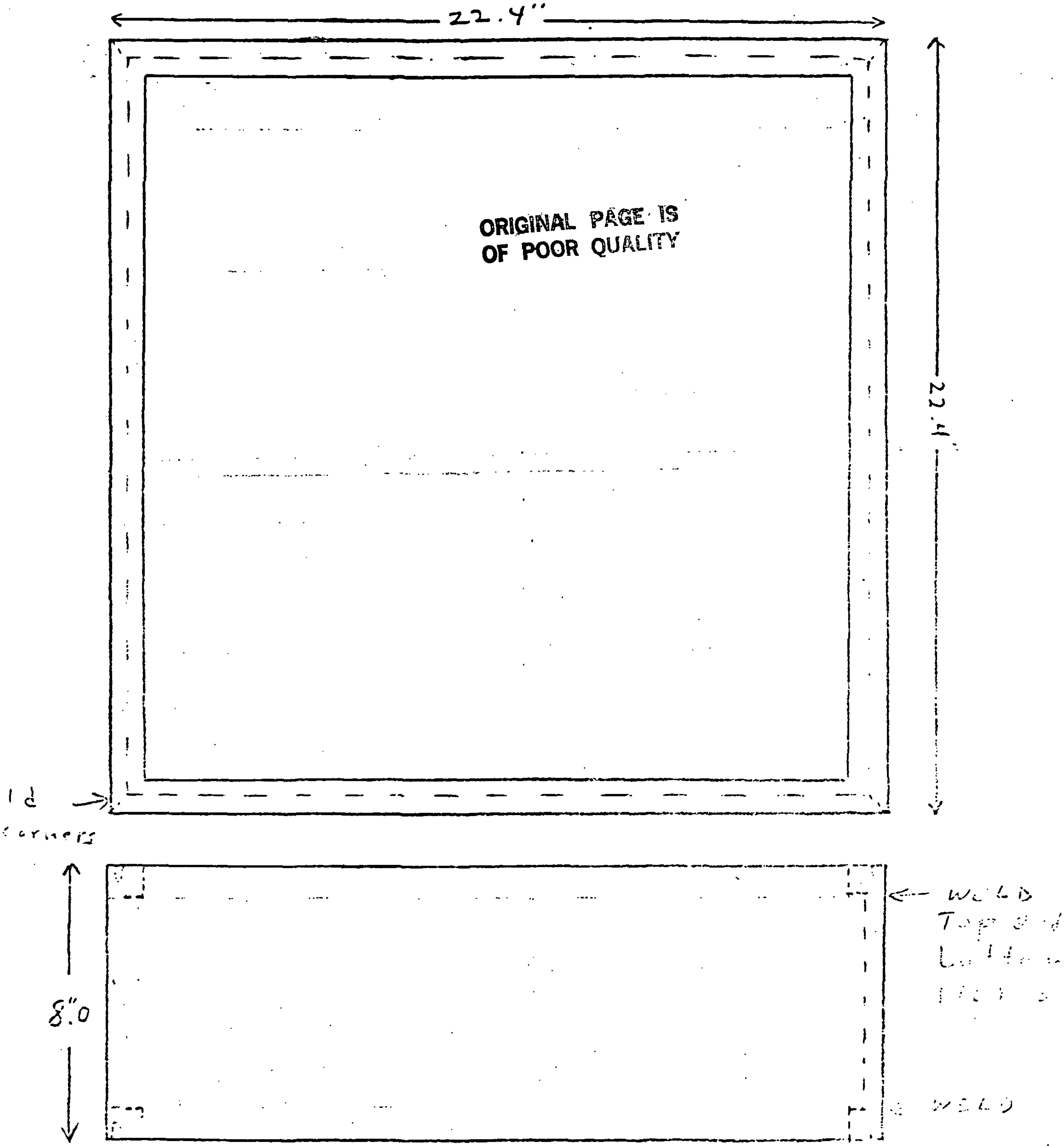
Bottom

Al-2024 T351



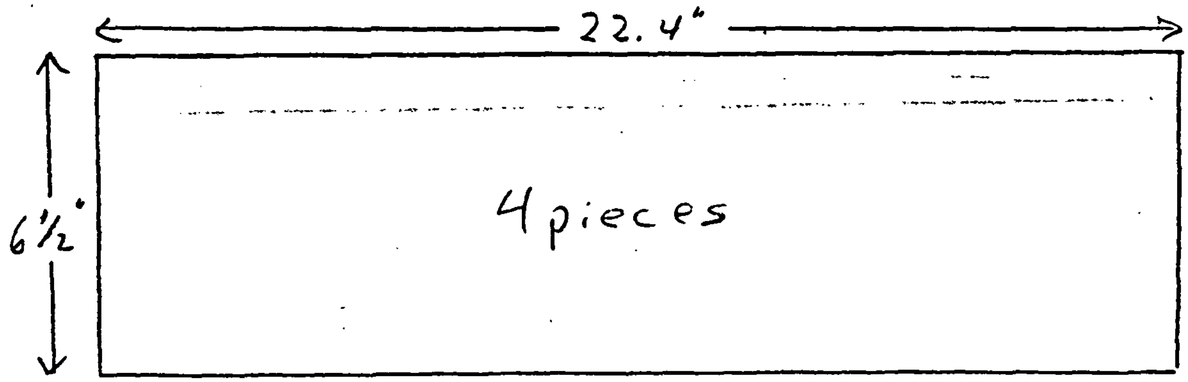
Ph99 6005-6
W.O. —
HX11 Detector
G. Garmire
10 NOV 77

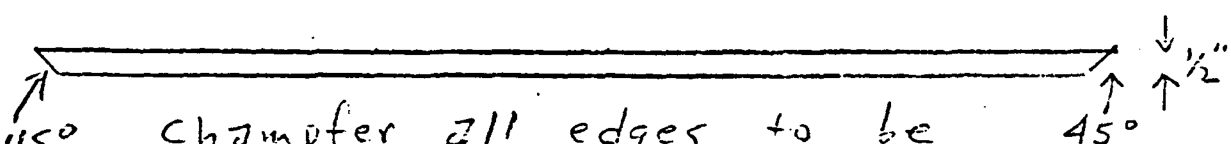
ASSEMBLY
Body



6061 Al welded & hardened to T

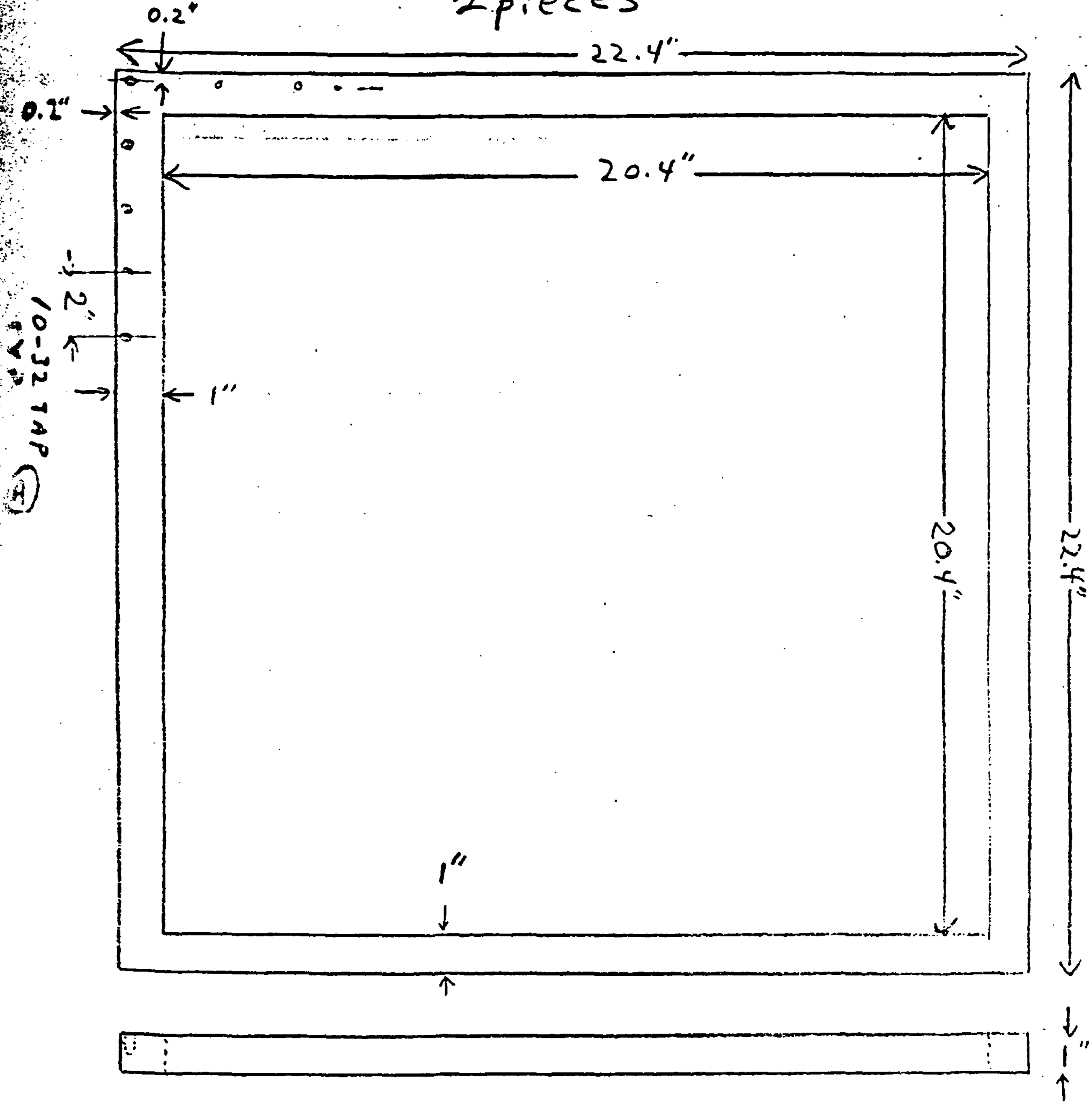
6061 Al





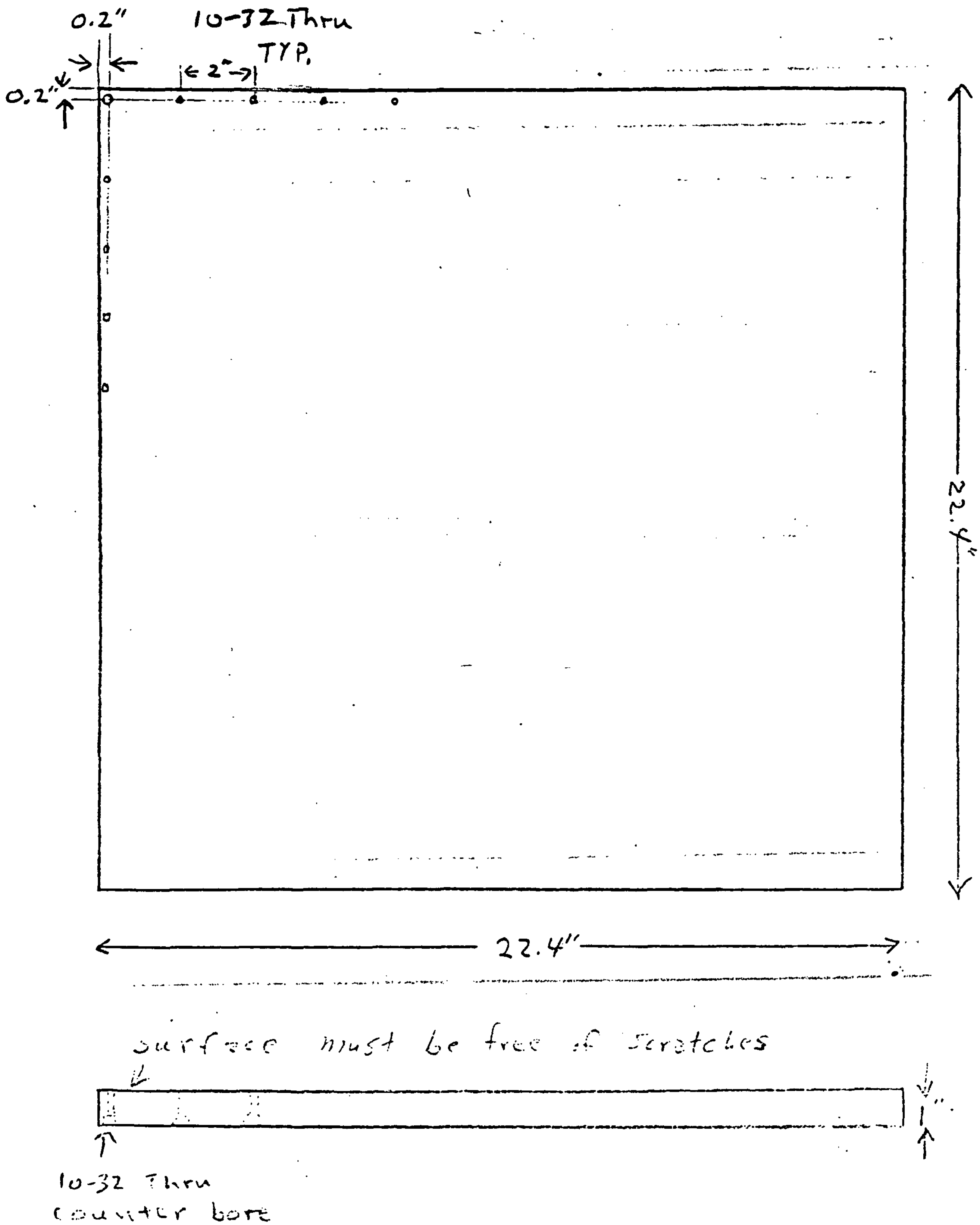
Champfer all edges to be welded

6061 Al
2 pieces



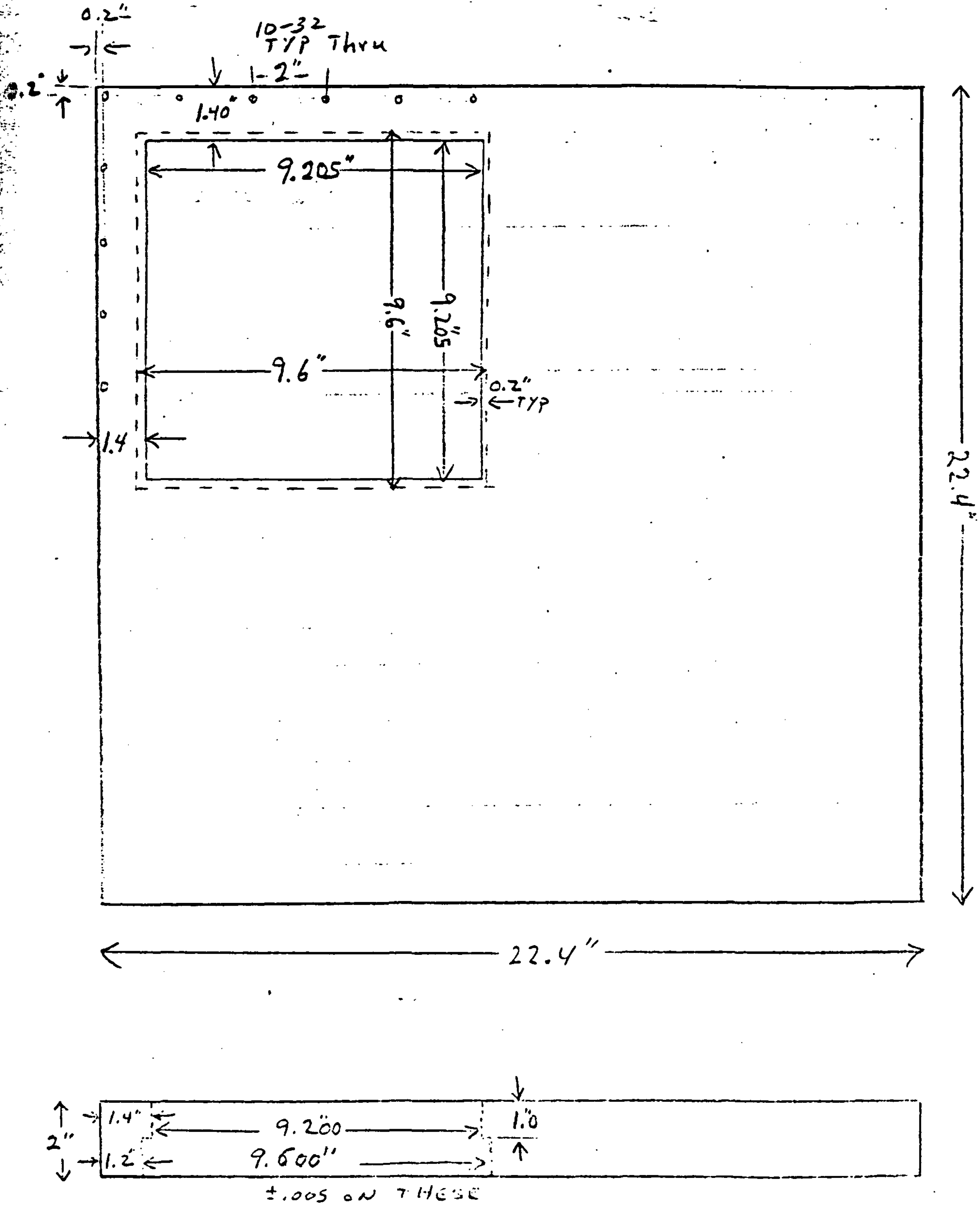
(A) These holes are to be put in after unit is assembled and machined

2024 Al T351



back plate

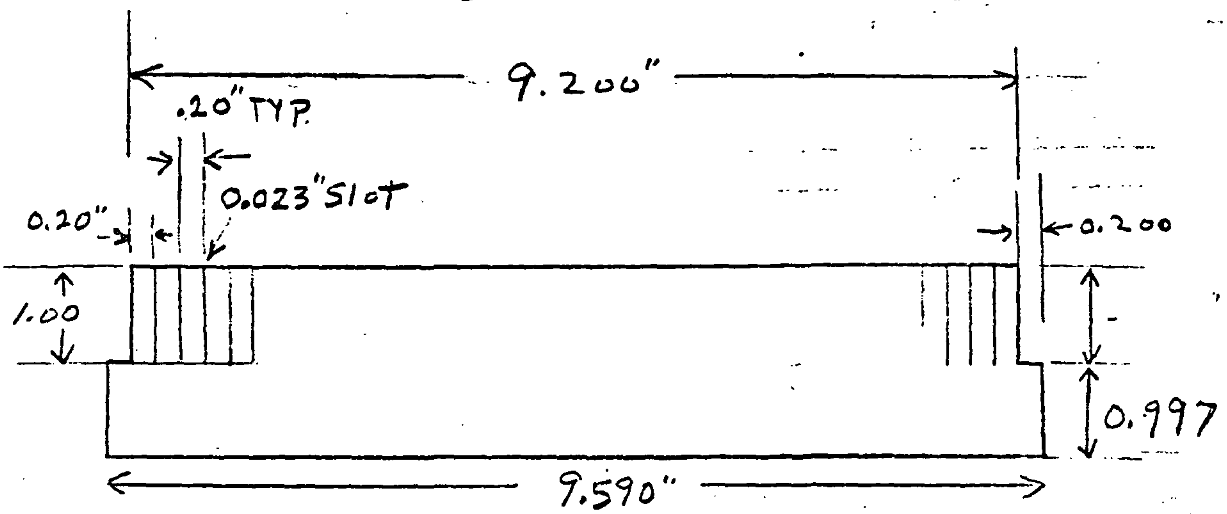
Top Plate
Al 2024 T351



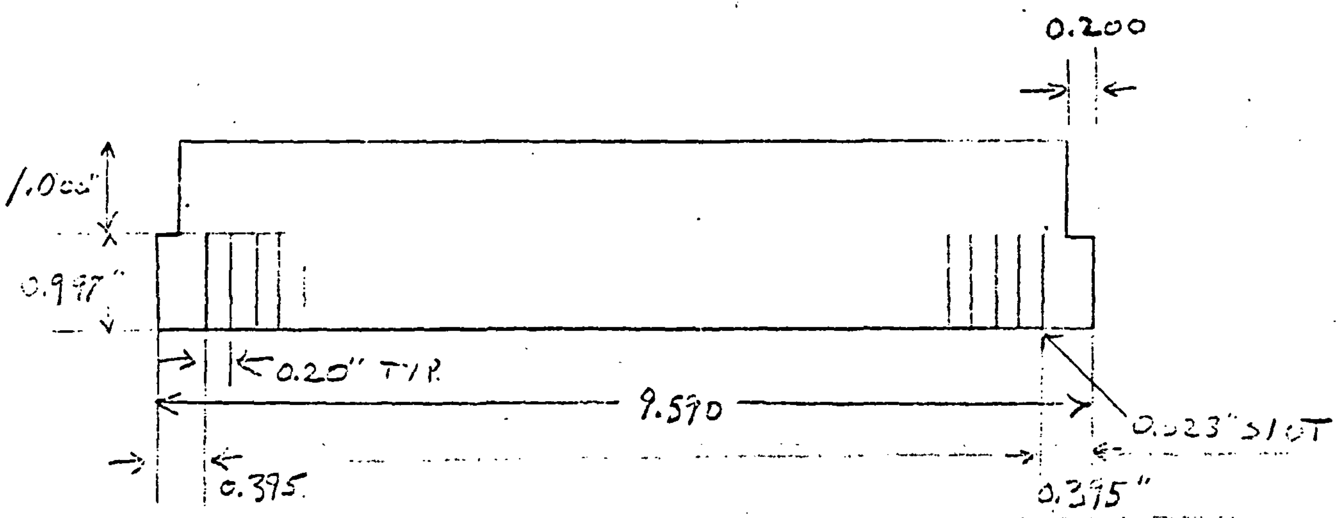
Collimators

2024 Al T351

0.020"



50 p...



APPENDIX B

HXII Gas Purification System

The three basic elements that make up the HXII gas system are the X-ray detector chamber, a Hydrox purifier (Matheson Gas Products), and a gas reservoir bottle.

As shown in the diagram, the gas is made to cycle by heating (180° F driving gas from reservoir) and cooling (-290° F condensing the gas back to a liquid). Each time the gas is cycled, it is filtered through the Hydrox gettering furnace. The furnace removes H_2O and O^2 from 100 ppm to 0.1 ppm at flow rates of up to 5 Lpm.

Note: For start-up and shut-down the purifier should be purged with dry nitrogen or some other inert gas.